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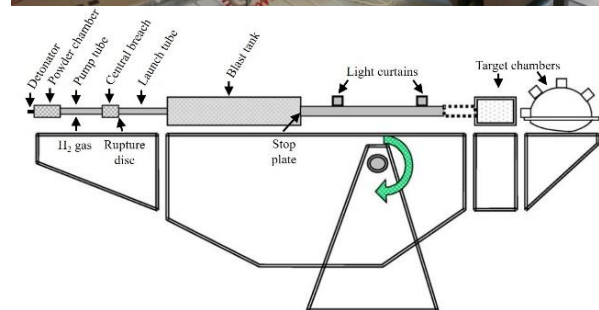
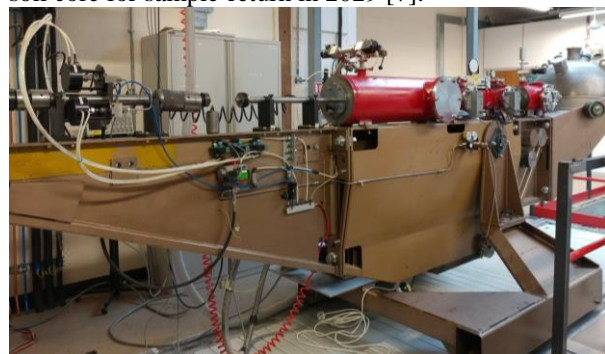
## CHARACTERISING THE TRANSFER OF BIOMARKERS WITHIN THE PHOBOS-MARS SYSTEM.

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**Introduction & Motivation:** As a discrete Solar System body, Phobos is not considered habitable owing to its extreme temperatures, harsh radiation environment and lack of water and nutrient supply [1]. However, its proximity to Mars and short orbital period led to the hypothesis that Phobos could sweep up particles ejected from large impacts into the martian surface [2]; models suggest that Phobos' regolith could include up to ~250 ppm of martian ejecta material [3,4]. Considering that Mars' surface has many "Special Regions" that could have been habitable in the past [5], it is not unreasonable to suggest that life could have developed and left behind biomarkers. An impact into one of these areas could eject material containing biologically-significant material, which could then deposit on the surface of Phobos.

The Japan Aerospace Exploration Agency (JAXA) plans to launch the Martian Moons eXploration (MMX) mission in 2024, with the main scientific goal of clarifying the origin of the two moons of Mars (Phobos and Deimos). To achieve this goal they plan to land, most likely on the larger moon Phobos, a CNES-DLR rover, for ground-truth analysis of the surface [6]; and then the main JAXA lander, equipped with a double sampler for collecting a soil scoop and >2cm soil core for sample-return in 2029 [7].



**Figure 1** AALGG at the Open University (top), Schematic diagram of the Light Gas Gun, showing the pivot point to switch between horizontal and vertical (bottom)

Considering the development of this mission, the search for scientific gains beyond the mission's main scientific goals has attracted recent interest. An appealing possibility is that the samples collected from the surface of Phobos could contain martian biomarkers. Simulations have recently taken place to investigate the feasibility of unsterilized material being transferred from Mars to Phobos (ESA's SterLim [8] and JAXA [9,10] teams). These simulations used specific microbes, making assumptions about the life involved in the transfer process, and also combined modelling and experimentation, which may have introduced uncertainties.

Therefore, further investigation into the feasibility of biological material being transferred from Mars to Phobos is necessary before returned samples and *in-situ* spacecraft data are analysed. In order to investigate this, this study proposes a series of impact and heating experiments to coherently simulate the conditions that martian rock, containing biological material, would experience throughout the transport process from Mars to Phobos. However, before these experiments can take place procedural and analytical development is required to address the shortcomings of past studies.

**Projectile manufacture:** The ultimate impact experiments of this study, simulating the transfer of biological material from Mars to Phobos, will rely on bespoke projectiles composed of multiple components, including martian analogue material and a variety of biomarkers in known concentrations. Past investigations have doped projectiles with organisms with a film covering [11] or by drilling holes into which biological samples can be loaded [8]. These methods introduce uncertainties associated with varying physical properties (density, porosity, viscosity and strength) across the projectile. Furthermore, they differ from the expected true scenario, where biological material could exist anywhere in the projectile, for example bound to mineral matrices [12].

Therefore, this study aims to develop the first bespoke projectile manufacturing procedure whereby a homogenous agglomerate can be made from multiple different raw materials at concentrations tailored to the specification of the experiment.

This new procedure addresses the uncertainties related to heterogenous projectiles, which, to the best of our knowledge, will allow us to experimentally simulate the compositional and physical properties of

biomarkers being delivered to Mars' moon from Mars more closely than ever before. Furthermore, the procedure offers a more efficient and easily repeatable alternative to producing projectiles for impact experiments. This makes hypervelocity impact experiments applicable to a multitude of new research questions, such as the transfer of biological material within Solar System environments and exoplanetary systems or within material science investigating how composite materials differ from homogenous materials in high pressure situations.

**Defining biomarkers:** Past investigations [8-10] have used Mars-analogue terrain to advise on the biological loading of martian material. However, this makes broad assumptions about the life that exists, or may have existed, on Mars. Therefore, this study will choose specific organic biomarkers, rather than whole organisms, to represent the building blocks essential for a wide range of organisms that could exist on the martian surface and those molecules present on Mars more likely to survive billions of years in a harsh environment [13].

For this study, these biomarkers must be used at concentrations that are within the detection limits of current analytical techniques. This is vital in order to discern whether biomarkers can survive the transfer process or not, and constrain the biological loading required for this material to be detectable within Phobos regolith by spacecraft and within returned samples.

In order to achieve this, projectiles will be produced with varying biomarker concentrations. These will then be characterised using instruments representative of current spacecraft payload and techniques that may be used to analyse returned samples, such as Gas Chromatography Mass Spectrometry (GS-MS) and Raman spectroscopy. This will support determining the sensitivity of those techniques to detect biomarkers within samples comparable in size to those that could to be analysed *in-situ* or collected by sample-return missions like MMX.

**Constraining contamination:** In order to achieve hypervelocity during shots with a Light Gas Gun, it must be operated in two-stage mode. The first stage involves the ignition of a shotgun cartridge, filled with gun powder and wadding, which propels a nylon piston. The second stage involves the piston compressing a light gas until a rupture disc bursts rapidly releasing the gas to accelerate the projectile down the launch tube (Fig. 1). During this process, unwanted carbon-based material from within the gun can be accelerated along with the projectile, which could contaminate the final impact in the target chamber. Characterisation of

this contamination is vital before conclusions are drawn on the survival of biomarkers.

This study will run a contamination test whereby filters will be placed in the target chamber during a two-stage shot to collect any particulates for compound-specific organic characterisation.

Furthermore, a compound-specific organic characterisation will be undertaken of the starting materials to be used future impact experiments, including Phobos regolith simulants and Mars analogue basalts.

By constraining the organic compounds present in the starting materials, as well as any contamination from the instruments, I will be able to differentiate organic compounds that have survived the impact process from contamination. This is vital to prevent false positive results.

**Summary and implications:** The bespoke projectile manufacturing procedure will be presented, along with the physical properties of the produced projectiles and preliminary results from test shots with the All-Axis Light Gas Gun at The Open University (Fig. 1).

Compound-specific organic characterisation of the doped projectiles will also be presented, which will be used to make inferences about the biomarker concentration required for detection by spacecraft and within returned samples. Finally, the starting conditions for future impact experiments will be presented highlighting carbon contamination produced by the gun and any organic compounds present within future impact experiment starting materials.

The results from the procedural and analytical development achieved by this study allow for future impact experiments investigating the feasibility of martian biomarkers surviving transport from Mars to Phobos to commence. However, crucially they also provide insight into the limitations of current analytical techniques in detecting biomarkers *in-situ* and in returned samples, which have major implications for current and future astrobiology missions.

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